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Mineral Consumption Forecasting: Standardizing and Comparing Forecasts

By John B. Bennett

UNITED STATES DEPARTMENT OF THE INTERIOR

(United States. Bureau of Mines)

Information Circular 9082

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By John B. Bennett

UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary

BUREAU OF MINES
Robert C. Horton, Director

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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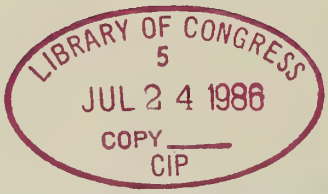

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

kmt	thousand metric tons	Mmt	million metric tons
lb	pound	Mst	thousand short tons
MM lb	million pounds	mt	metric ton

Mineral Consumption Forecasting: Standardizing and Comparing Forecasts

By John B. Bennett[1]

ABSTRACT

This Bureau of Mines report presents a method of standardizing forecasts of mineral consumption that attempts to resolve the problems caused by the use of different data bases, different definitions of minerals consumption, and different base years for making projections. Using this method, forecasts of U.S. and world mineral consumption, in the year 2000, for nine commodities (aluminum, chromium, cobalt, copper, manganese, nickel, tin, tungsten, and zinc) are standardized and compared. Also selected forecasts or associated growth rates are used to generate implied values of consumption for 1980-83, which are then compared to actual values of consumption for 1980-83. The economic growth predictions underlying these forecasts are examined, and some general conclusions are drawn. A description of each methodology used to generate these forecasts is given in an appendix.

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INTRODUCTION

The Bureau of Mines develops forecasts of the future consumption of minerals and materials to aid in identifying and anticipating changes that might affect the national interest. Anticipating changes in the level and distribution of mineral demand is important for formulating long-run policies pertaining to the adequacy of mineral supply, for planning investment in U.S. mining facilities, for forming trade and development policies, and for planning the modernization and growth of rich and poor nations alike. The Bureau forecasts, made on both a national and a global basis, assist the Secretary of the Interior in carrying out his responsibilities under the Strategic and Critical Materials Stock Piling Act, which directs him to investigate the production and utilization of minerals and materials, and also assist him in helping to ensure the continued strength of the domestic mineral and material economy and the maintenance of an adequate mineral and material base. Forecasts of future consumption are published every 5 years in detail in *Mineral Facts and Problems* and, on an interim basis as necessary, in *Mineral Commodity Profiles*. The Bureau forecasts provide high, low, and probable levels of mineral and material consumption in the United States and the rest of the world as a whole. The Bureau also forecasts U.S. consumption by end use.

The comparison of forecasts from different sources, accompanied by a knowledge of how those forecasts were generated, offers the advantage of insight into how others view the world, and the possibility of learning from those views. The comparison of forecasts, however, frequently is hindered by differences in definitions, use of different base years, and other factors.

In this study, a method of standardizing forecasts of mineral consumption is presented that attempts to resolve the problems caused by the use of different data bases, different definitions of minerals consumption, and different base years for making projections. These problems have previously remained unresolved, or have been addressed in a patchwork fashion, in earlier works that presented forecasts of different forecasters (3).[2] Using the method described here, forecasts for nine minerals for the year 2000 are standardized and compared, for the United States and the world. The forecasts were for consumption of the following commodities: aluminum, chromium, cobalt, copper, manganese, nickel, tin, tungsten, and zinc. The forecasts examined in some detail are from publications by Fischman (*4*), Leontief (*9*), Malenbaum (*11*), Ridker (*13*), and the Bureau of Mines (*14*). Also selected forecasts or associated growth rates are used to generate implied values of consumption for 1980-83, which are then compared to actual values of consumption for 1980-83. The economic growth predictions underlying these forecasts are then examined, and some general conclusions are drawn. A description of each methodology used to generate these forecasts is given in appendix A.

FORECAST STANDARDIZATION AND COMPARISON

PROBLEMS IN COMPARING MINERAL CONSUMPTION FORECASTS

In comparing forecasts of mineral consumption from various sources, several problems arise. First, the definition of consumption may vary. The consumption of a particular commodity may be defined, for example, as apparent consumption, primary consumption, primary plus secondary consumption, or industrial consumption. Sometimes the distinctions between such definitions are made clear when data are presented, sometimes not. Moreover, even when the same definition of consumption is used, the underlying data series used may not be the same. There are various sources of mineral consumption data, and over time, revisions, updates, and changes in definitions occur, not necessarily at the same time, for the different sources. Revisions of data series, in particular, occasionally go back a number of years. Also, the various data series may reflect different degrees of processing—for example, ore series are used occasionally by some forecasters. Third, when forecasts are made at different points in time, the data base will cover a different time span, which might lead to different evaluations of likely trends.

The data in table 1 illustrate these problems. These mineral consumption forecasts were gathered from the works reviewed in appendix A. The forecasts were made at approximately the same time; indeed one of the reasons they were picked was to avoid as much as possible the problem of forecasts made when world conditions are quite different. The Fischman, Ridker, and Bureau of Mines projections were published in 1980, Malenbaum's in 1977, and Leontief's in 1983. The forecasts are of U.S. and world consumption in the year 2000, for the following commodities: aluminum, chromium, cobalt, copper, manganese, nickel, tin, tungsten, and zinc. They are given in their original units in table 1—short tons, metric tons, and pounds. In table 2, the forecasts are all converted to the same unit, thousand metric tons. The procedures used for converting the forecasts are given in the table notes.

Of the five sets of forecasts, four different definitions of consumption are used: apparent, primary, gross domestic demand, and total consumption. Also, while both Fischman and Malenbaum use the apparent consumption concept, Fischman's manganese and chromium projections are in terms of metal, while Malenbaum's are in terms of the respective ores. The ore figures were converted to refined metal using the same ratios used in the Global 2000 (*3*) study for this purpose. Mineral analysts could disagree with these ore conversion ratios, which serves to illustrate the problem. Since the forecasts are for similar but not identical items, numerical comparisons of the forecasts with each other are strained.

Comparisons of forecasts to currently available data are subject to the same kinds of problems. A series of forecasts from various sources, compared to current data, might offer useful information to decision makers or to those currently at work on their own projections. After all, many decisions are made on the basis of forecasts, and new forecasts are generated relatively often. One might argue that a forecast for a future time period, for example the year 2000, cannot be evaluated until that year arrives. At that point its accuracy could easily be determined. However, such forecasts

[2]Italicized numbers in parentheses refer to items in the list of references preceding appendix A.

do have implications for the intervening years. In 1999, to take an extreme example, one should be able to evaluate whether or not consumption in the following year will approximate a given forecast for 2000. In a more general sense, these forecasts, in conjunction with the base period used to generate them, have implications for the general path consumption will travel on the way to 2000. If a forecaster, in say 1980, expects consumption of a given mineral to decline by 2000, and instead it increases every year in the 1981-85 period, one might properly doubt the accuracy of the forecast of decline. Of course, quite a different evaluation could result some years down the road.

Table 1.—Mineral consumption forecasts for the year 2000
(Data in original units)

Commodity and area	Fischman[1] (*4*)	Leontief[2] (*9*)	Malenbaum[3] (*11*)	Ridker[4] (*13*)	BuMines[5] (*14*)
Aluminum:					
U.S.	11.1 Mmt	14.3 Mmt	13,073.0 kmt	16,493.0 Mst	17,200.0 Mst
World	46.2 Mmt	ND	36,516.0 kmt	60,965.0 Mst	63,700.0 Mst
Chromium:					
U.S.	ND	1,150.0 kmt	1,601.0 kmt	1,107.0 kmt	1,240.0 Mst
World	6.7 Mmt	8,220.0 kmt	16,018.0 kmt	2,016.0 Mst	7,950.0 Mst
Cobalt:					
U.S.	33.5 MMlb	ND	16,608.0 mt	19.0 Mst	40 MMlb
World	96.0 MMlb	ND	57,532.0 mt	123.0 Mst	107 MMlb
Copper:					
U.S.	3.1 Mmt	4.3 Mmt	3,202.0 kmt	3,265.0 Mst	4,600.0 kmt
World	16.3 Mmt	ND	16,839.0 kmt	16,418.0 Mst	23,600.0 kmt
Manganese:					
U.S.	ND	2,390.0 kmt	4,002.0 kmt	2,458.0 Mst	2,000.0 Mst
World	17.1 Mmt	35,600.0 kmt	48,060.0 kmt	10,765.0 Mst	19,600.0 Mst
Nickel:					
U.S.	ND	355.8 kmt	280.1 kmt	525.0 Mst	600.0 Mst
World	ND		1,314.1 kmt	2,122.0 Mst	2,500.0 Mst
Tin:					
U.S.	ND	113.0 kmt	67.0 kmt	114.0 Mst	65,000.0 kmt
World	ND	727.0 kmt	393.0 kmt	582.0 Mst	313,800.0 kmt
Tungsten:					
U.S.	ND	17.4 kmt	12,006.0 mt	15.0 Mst	61 MMlb
World	ND	125.0 kmt	92,637.0 mt	69.0 Mst	219 MMlb
Zinc:					
U.S.	1.5 Mmt	3.5 Mmt	2,001.0 kmt	2,616.0 Mst	1,800.0 kmt
World	10.7 Mmt	ND	12,022.0 kmt	12,819.0 Mst	10,600.0 kmt

ND No data.
[1] Apparent consumption.
[2] Primary consumption; technological change assumed.
[3] Apparent consumption; Cr and Mn as ore, primary Al.
[4] Gross domestic demand for U.S. data; total consumption, primary and secondary, for world data; base scenario for U.S. data; standard case for world data.
[5] Probable total consumption, primary and secondary, for both U.S. and world data.

Table 2.—Projected consumption in 2000
(All data converted to thousand metric tons)[1]

Commodity and area	Fischman[2] (*4*)	Leontief[3] (*9*)	Malenbaum[4] (*11*)	Ridker[5] (*13*)	BuMines[6] (*14*)
Aluminum:					
United States	11,100.0	14,340.0	13,073.0	14,962.4	15,603.8
World	46,200.0	ND	36,516.0	55,307.4	57,788.6
Chromium:					
United States	ND	1,150.0	438.7	1,004.3	1,124.9
World	6,670.0	8,220.0	4,388.9	1,828.9	7,212.2
Cobalt:					
United States	15.2	ND	16.6	17.2	18.1
World	43.5	ND	57.5	111.6	48.5
Copper:					
United States	3,100.0	4,290.0	3,202.0	2,962.0	4,600.0
World	16,300.0	ND	16,839.0	14,894.4	23,600.0
Manganese:					
United States	ND	2,390.0	1,921.0	2,229.9	1,814.4
World	17,100.0	35,600.0	23,068.8	9,766.0	17,781.1
Nickel:					
United States	ND	355.8	280.1	476.3	544.3
World	ND	ND	1,314.1	1,925.1	2,268.0
Tin:					
United States	ND	113.0	67.0	103.4	65.0
World	ND	727.0	393.0	528.0	313.8
Tungsten:					
United States	ND	17.4	12.0	13.6	27.7
World	ND	125.0	92.6	62.6	99.3
Zinc:					
United States	1,470.0	3,520.0	2,001.0	2,373.2	1,800.0
World	10,730.0	ND	12,022.0	11,629.4	10,600.0

ND No data.
[1] Short tons multiplied by 0.9072, metric tons divided by 1,000, million metric tons multiplied by 1,000, pounds converted to short tons (divided by 2,000), manganese ore multiplied by 0.48, chrome ore multiplied by 0.274.
[2] Apparent consumption.
[3] Primary consumption; technological change assumed.
[4] Apparent consumption; Cr and Mn as ore, primary Al.
[5] Gross domestic demand for U.S. data; total consumption, primary and secondary, for world data; base scenario for U.S. data; standard case for world data.
[6] Probable total consumption, primary and secondary, for both U.S. and world data.

A STANDARDIZATION METHODOLOGY AND EXAMPLES

The problem in mineral consumption forecast comparison is identical to the familiar apples and oranges problem. How do you compare values when they measure different things? The problem would be eliminated if the forecasts could be recast into the same units or into a unit-free form. The following standardization procedure was developed to accomplish both these ends. The procedure is demonstrated first with a hypothetical example and then with data drawn from the various works reviewed in appendix A.

In the hypothetical example given in table 3, it is assumed that there are two forecasters, forecaster X and forecaster Y, using the base years 1975 and 1980, respectively. Forecaster X projects the level of consumption in the year 2000 to be 2,500 units, while forecaster Y projects that level to be 3,000 units. In other words, forecaster X expects consumption of this commodity to be 2½ times its 1975 level in the year 2000, while forecaster Y expects consumption of the commodity, in the year 2000, to be twice its 1980 level. Suppose that another set of data is available, covering both the years 1975 and 1980. For the purpose of illustration, this latter set of data will be called the basic data. Suppose that both forecasters X and Y had used the basic data values for 1975 (1,200) and 1980 (1,600), respectively, instead of their original values, in making their projections. Then, assuming they still projected the same rate of increase between their base years and the year 2000, the new or rebased projections would be 3,000 and 3,200 units, respectively. Now if the basic data (1,200 and 1,600) are in the same units, the new projections will also be in the same units, and comparisons can be readily made.

Table 3.—Standardization Example

Data Source	Base Year		Projection (2000)	
	1975	1980	Original	Rebased
Forecaster X	1,000	NAp	2,500	3,000
Forecaster Y	NAp	1,500	3,000	3,200
Basic data	1,200	1,600	NAp	NAp

NAp Not applicable.

This procedure was carried out on data collected from the works reviewed in appendix A. First, the base data from the various works were collected. None of the studies reviewed used the same base data set, even those published at the same time. The various bases used included a 1971-75 average, a 1975-77 average, 1978, 1972, 1970, and 1971. All of the base year data, with the exception of Ridker's, who used 1971, were published in the works reviewed. Each forecast for the year 2000 was then divided by the base year figure. The resulting ratios showed the amount of increase between the base year and the year 2000.

Next, a basic table of mineral consumption was constructed, for the United States and the world, using the latest data available at the time of writing. This basic table included values for each of the nine commodities listed in table 1 over the period 1970-83; values of world chromium and manganese production are used in this table to represent consumption data for these minerals, as no world consumption data were available. The period 1970-83 was used because it included every base year used by the various forecasters considered in this study. These data are presented in table 4. From this basic table, an adjusted version of the base data used by the various forecasters was compiled. A new value for each base year (or average) used

Table 4.—Mineral consumption, 1970-83, thousand metric tons

Year and area	Al	Cr[1]	Co	Cu	Mn[1]	Ni	Sn	W	Zn
1970:									
United States	3,871.0	498.1	7.3	1,883.0	1,203.9	202.7	66.8	8.2	1,235.0
World	12,160.1	1,868.8	22.1	7,283.7	8,204.7	566.6	227.0	ND	5,055.9
1971:									
United States	4,347.3	366.5	6.2	1,880.0	1,061.4	180.2	62.1	6.7	1,199.0
World	12,936.9	1,981.3	18.4	7,349.7	9,070.2	516.2	235.2	31.8	5,172.3
1972:									
United States	5,025.9	508.0	8.8	2,185.0	1,239.2	213.5	61.2	7.1	1,377.0
World	14,156.8	1,981.3	26.5	7,984.7	9,082.9	573.7	235.2	35.5	5,709.4
1973:									
United States	5,941.0	545.2	10.0	2,208.0	1,409.8	239.4	65.1	9.9	1,474.0
World	16,359.9	1,999.5	29.9	8,445.9	9,707.0	652.3	253.3	39.2	6,283.0
1974:									
United States	5,625.0	567.0	10.9	2,210.0	1,353.5	256.8	72.6	10.7	1,311.0
World	16,705.9	2,207.2	29.2	8,390.8	9,253.4	703.8	243.9	37.4	5,998.1
1975:									
United States	4,079.0	372.0	6.4	1,467.0	1,027.9	198.9	53.7	6.3	1,331.0
World	13,891.5	2,540.2	21.8	7,457.5	9,797.8	576.2	218.0	32.7	5,092.4
1976:									
United States	5,196.0	479.9	9.1	1,946.0	1,237.4	220.5	57.9	7.8	1,298.0
World	16,857.8	2,669.0	24.5	8,538.7	9,979.2	670.3	239.1	36.1	5,764.4
1977:									
United States	5,849.0	517.1	8.2	2,045.0	1,381.7	231.3	58.3	8.5	1,154.0
World	17,563.3	2,883.1	24.5	9,056.4	8,709.1	642.2	231.2	42.2	5,808.4
1978:									
United States	6,111.0	535.2	9.1	2,369.0	1,236.5	247.4	58.9	10.1	1,154.0
World	18,569.0	2,820.5	25.9	9,530.4	8,618.4	697.4	231.5	48.6	6,209.3
1979:									
United States	6,030.0	553.4	8.6	2,432.0	1,134.0	204.8	53.5	10.8	932.0
World	19,452.8	2,935.7	24.5	9,829.8	9,797.8	750.2	236.8	51.2	6,323.8
1980:									
United States	5,223.0	532.5	7.7	2,175.0	933.5	186.7	46.7	9.9	951.0
World	18,773.0	2,972.9	22.7	9,361.3	9,707.0	715.3	234.6	49.1	6,124.3
1981:									
United States	5,209.0	462.7	5.9	2,278.0	931.7	186.9	52.5	10.3	1,146.0
World	18,216.5	2,786.0	18.6	9,508.0	8,437.0	663.0	225.6	47.0	5,994.4
1982:									
United States	4,811.0	289.4	5.0	1,761.0	609.6	163.7	30.3	6.1	869.0
World	17,823.5	2,489.4	16.3	9,067.6	8,709.1	651.8	215.4	40.0	5,916.9
1983:									
United States	5,442.0	298.5	7.3	2,020.0	606.0	185.4	38.1	6.5	1,005.0
World	19,358.8	2,490.3	20.9	9,113.2	7,983.4	683.0	215.2	41.1	6,132.0

ND No data. [1] World production data used to represent world consumption data.

Sources: U.S. Bureau of Mines, *Mineral Facts and Problems*, 1980 and 1985 Editions, for all data except as follows: Cobalt data from William Kirk, commodity specialist, Bureau of Mines; world data for Al, Cu, Ni, Sn, and Zn from *World Metal Statistics*; world data for W from *Tungsten Statistics*.

by each forecaster was chosen (or computed). For example, if the forecaster used 1972 values as the base of his U.S. predictions, as did Leontief, new values for 1972 were taken from the basic table to form an adjusted base for Leontief. Thus, the values of the base year used by each forecaster were cast into the same units, from the same table. The original and adjusted data bases are shown in tables 5 and 6, respectively. Table 7 shows the ratios of the values of table 5 to those of table 6. These ratios clearly show the differences in the underlying data bases and demonstrate the need for such an adjustment.

Values from the new, "adjusted" data base were then used, along with the ratio of each forecast for 2000 to the original base, to recompute the 2000 predictions. This was done for each forecaster, except Ridker, since the latter's base data were not known. Although the base years of the various forecasts in this recomputed form were still different, all predictions were now based on data in the same units coming from the same table. These recomputed or rebased values are given in table 8. The recomputed values were then divided by the actual values of 1980 consumption from table 4. The resulting ratios provide a unit-free method of comparing the expected change between 1980 and 2000 among the various forecasters. Since these ratios determine growth rates between 1980 and 2000, this method can also be used to standardize growth rates– i.e., the effective growth rates for various forecasters between a common year (in this case 1980) and the year 2000 can be determined. The ratios are given in table 9 and are displayed graphically in figure 1.

Table 5.—Original base, thousand metric tons

Commodity and area	Fischman[1] (*4*)	Leontief[2] (*9*)	Malenbaum[3] (*11*)	BuMines[4] (*14*)
Aluminum:				
United States	5,480.0	4,800	4,388.1	6,111.8
World	16,050.0	ND	12,248.7	18,270.1
Chromium:				
United States	ND	460.5	314.8	498.96
World	3,680.0	2,100	1,901.8	3,538.1
Cobalt:				
United States	9.1	ND	7.282	9.18
World	26.8	ND	23.434	24.66
Copper:				
United States	1,890.0	1,760	1,886.1	2,380
World	8,370.0	ND	7,922.7	10,100
Manganese:				
United States	ND	1,236.8	926	1,236.5
World	9,000.0	8,240	9,762.7	8,692.8
Nickel:				
United States	ND	152	160.5	217.4
World	ND	ND	618.4	881.8
Tin:				
United States	ND	49.85	52.6	53.9
World	ND	222	232.5	281
Tungsten:				
United States	ND	6.45	6.51	10.21
World	ND	33.6	40.18	47.29
Zinc:				
United States	1,080.0	1,310	1,159.8	1,229
World	5,750.0	ND	5,506.26	6,779

ND No data. [1] Average 1973-77. [2] 1972 U.S. data, 1970 world data. [3] Average 1971-75. [4] 1978.

Table 6.—Adjusted base, thousand metric tons

Commodity and area	Fischman[1] (*4*)	Leontief[2] (*9*)	Malenbaum[3] (*11*)	BuMines[4] (*14*)
Aluminum:				
United States	5,298.0	5,025.9	5,003.6	6,111.8
World	16,275.7	ND	14,810.2	18,569.5
Chromium:				
United States	ND	508.0	471.7	535.2
World	2,459.8	1,868.8	2,141.9	2,820.5
Cobalt:				
United States	8.9	ND	8.4	9.1
World	26.0	ND	25.2	25.9
Copper:				
United States	1,975.2	2,185.0	1,990.0	2,369.0
World	8,377.9	ND	7,925.7	9,530.4
Manganese:				
United States	ND	1,239.2	1,218.4	1,236.5
World	9,489.3	8,204.7	9,382.3	8,618.4
Nickel:				
United States	ND	213.5	217.8	247.4
World	ND	ND	604.5	697.4
Tin:				
United States	ND	61.2	62.9	58.9
World	ND	227.0	235.8	231.5
Tungsten:				
United States	ND	7.1	8.2	10.1
World	ND	ND	35.3	48.6
Zinc:				
United States	1,313.6	1,377.0	1,338.4	1,154.0
World	5,789.3	ND	5,651.0	6,209.3

ND No data. [1] Average 1973-77. [2] 1972 U.S. data, 1970 world data. [3] Average 1971-75. [4] 1978.

Table 7.—Original base divided by adjusted base

Commodity and area	Fischman (*4*)	Leontief (*9*)	Malenbaum (*11*)	BuMines (*14*)
Aluminum:				
United States	1.03	0.96	0.88	1.00
World	.99	ND	.83	.98
Chromium:				
United States	ND	.91	.67	.93
World	1.50	1.12	.89	1.25
Cobalt:				
United States	1.02	ND	.87	1.01
World	1.03	ND	.93	.95
Copper:				
United States	.96	.81	.95	1.00
World	1.00	ND	1.00	1.06
Manganese:				
United States	ND	1.00	.76	1.00
World	.95	1.00	1.04	1.01
Nickel:				
United States	ND	.71	.74	.88
World	ND	ND	1.02	1.26
Tin:				
United States	ND	.81	.84	.92
World	ND	.98	.99	1.21
Tungsten:				
United States	ND	.91	.79	1.01
World	ND	ND	1.14	.97
Zinc:				
U.S.	.82	.95	.87	1.06
World	.99	ND	.97	1.09

ND No data.

Table 8.—1980 consumption and rebased projected consumption in 2000, thousand metric tons

Commodity and area	Actual 1980[1]	Fischman (*4*)	Leontief (*9*)	Malenbaum (*11*)	BuMines (*14*)
Aluminum:					
United States	5,223.0	10,731.4	15,552.6	14,906.7	15,601.8
World	18,773.0	46,849.7	ND	44,152.4	58,735.6
Chromium:					
United States	532.5	ND	1,268.6	657.4	1,206.7
World	2,972.9	4,458.4	7,315.0	4,943.0	5,749.4
Cobalt:					
United States	7.7	14.9	ND	19.1	17.9
World	22.7	42.2	ND	61.8	50.9
Copper:					
United States	2,175.0	3,239.7	5,325.9	3,378.4	4,578.7
World	9,361.3	16,315.4	ND	16,845.4	22,269.1
Manganese:					
United States	933.5	ND	2,394.6	2,527.6	1,814.4
World	9,707.0	18,029.7	35,447.5	22,169.9	17,628.9
Nickel:					
United States	186.7	ND	499.8	380.1	619.4
World	715.3	ND	ND	1,284.6	1,793.7
Tin:					
United States	46.7	ND	138.7	80.1	71.0
World	234.6	ND	743.4	398.6	258.5
Tungsten:					
United States	9.9	ND	19.2	15.1	27.5
World	49.1	ND	ND	81.4	102.1
Zinc:					
United States	951.0	1,788.0	3,700.0	2,309.1	1,690.2
World	6,124.3	10,803.3	ND	12,338.0	9,709.2

ND No data. [1] Data from Mineral Facts and Problems, 1985.

Table 9.—Rebased projected consumption in 2000 divided by 1980 actual consumption

Commodity and area	Fischman (*4*)	Leontief (*9*)	Malenbaum (*11*)	BuMines (*14*)
Aluminum:				
United States	2.05	2.98	2.85	2.99
World	2.50	ND	2.35	3.13
Chromium:				
United States	ND	2.38	1.23	2.27
World	1.50	2.46	1.66	1.93
Cobalt:				
United States	1.93	ND	2.48	2.32
World	1.86	ND	2.73	2.24
Copper:				
United States	1.49	2.45	1.55	2.11
World	1.74	ND	1.80	2.38
Manganese:				
United States	ND	2.57	2.71	1.94
World	1.86	3.65	2.28	1.82
Nickel:				
United States	ND	2.68	2.04	3.32
World	ND	ND	1.80	2.51
Tin:				
United States	ND	2.97	1.72	1.52
World	ND	3.17	1.70	1.10
Tungsten:				
United States	ND	1.93	1.52	2.77
World	ND	ND	1.66	2.08
Zinc:				
United States	1.88	3.89	2.43	1.78
World	1.76	ND	2.01	1.59

ND No data.

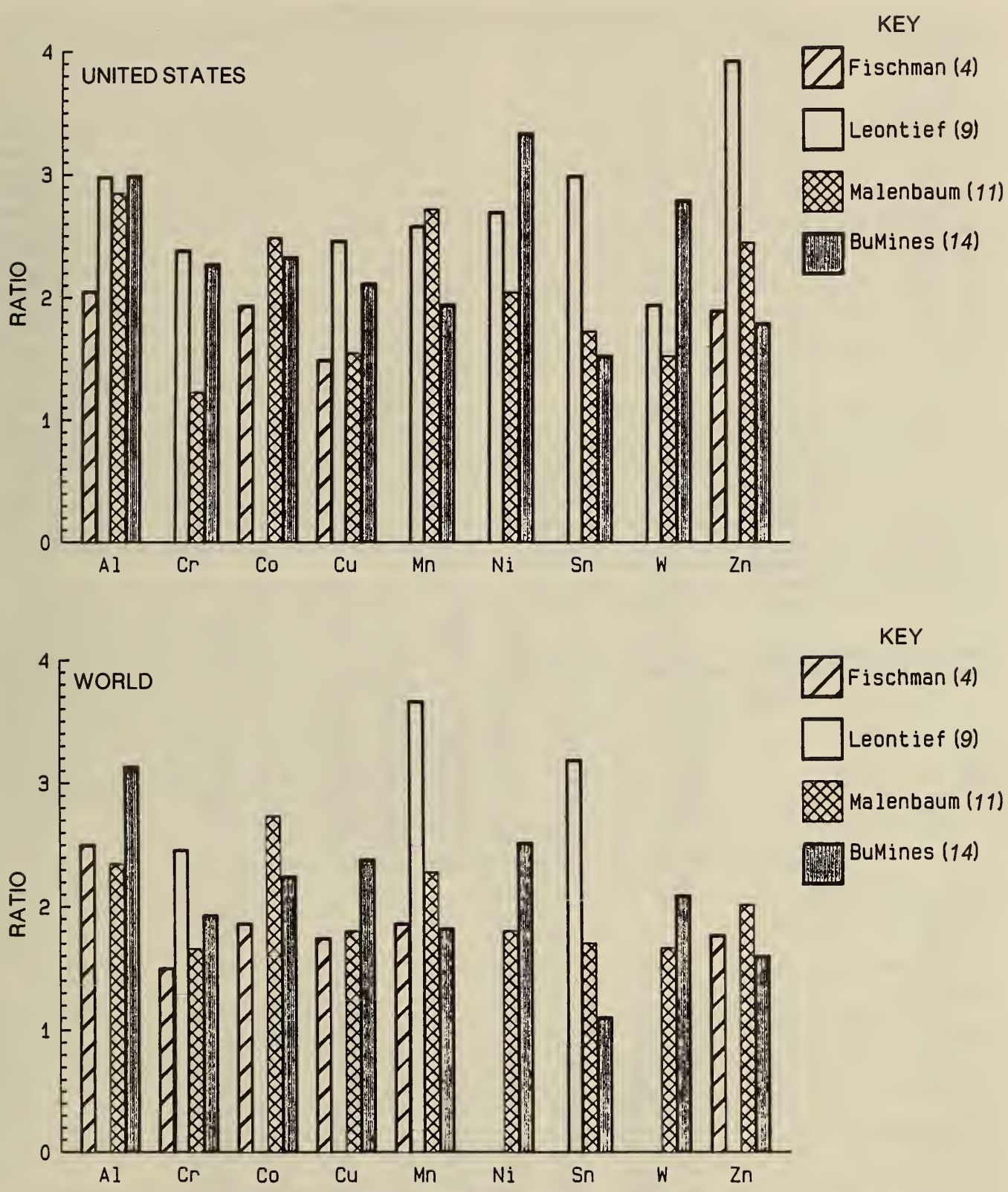

Figure 1.—Rebased consumption projections for 2000 divided by 1980 actual consumption: United States and world.

The related problem of comparing forecasts to currently available data was approached in the following manner. If the base year and base data are given, along with the forecast, growth rates of consumption can be computed. Such growth rates are in fact commonly included in studies containing forecasts. With these growth rates, and the base year data, values of consumption can be computed for the interval of years between the base year and forecast year. These values would not be expected to be equal to actual values every year, or even any year, of the forecast period, since mineral consumption fluctuates from year to year, depending on, among other things, the business cycle. Still these values, when accumulated over a period of years, should give an idea of the cumulative consumption the forecaster expected in that period. This sum would also give an idea, when compared to actual values, of how well that forecast seemed to fit the real world at some point in time. Of course, the accuracy of a given forecast, as judged by this method, would vary with the period chosen as the evaluation period.

A hypothetical example of this approach is given in table 10. Forecaster X (of table 3) projected a 2½ times increase in consumption between 1975 and 2000. This rate of increase implies a growth rate of 3.7%. Using the base year of forecaster X (1975) and the value of that year (1,200) from the basic data series of table 3, values of consumption for 1980, 1981, 1982, and 1983 were determined; these values are simply those values that result in the years 1980, 1981, 1982, and 1983 from a growth of 3.7% beginning in 1975 at a value of 1,200. Accompanying those values in table 10 are "actual" values, meant to represent actual mineral consumption, which does not grow along a smooth trend, but rather fluctuates. These "actual" values are also assumed to come from the basic data series and therefore are in the same units as the computed values. The sums of the two sets of 1980-83 values are shown; in this case, the sum of the "implied" values is fairly close to the sum of the "actual" values.

Table 10.—Comparison example: Trend versus actual with forecaster X's growth rate (3.7%) and new base (1,200 units in 1975)

Year	Forecaster X trend values	"Actual" values
1980	1,440	1,200
1981	1,488	1,400
1982	1,548	1,200
1983	1,608	1,800
Total	6,084	5,600

This approach was carried out on the data gathered in this study in the following manner. First, growth rates that included the period 1980-83 were gathered from the various studies, if they were available. If they were unavailable, they were computed. These growth rates are given in table 11. These growth rates are not strictly comparable, since they cover various periods of time. Next, using these growth rates and the adjusted data base for each forecaster, "implied" values of consumption for 1980, 1981, 1982, and 1983 were calculated. These values were summed over each commodity, for each forecaster, and divided by the actual value of consumption over that period, taken from the basic table (table 4). The resulting ratios, given in table 12 and displayed graphically in figure 2, were computed from growth rates projected—or computed using projections—by Fischman, Leontief, Malenbaum, Ridker, and the Bureau. Appendix B contains similar ratios calculated on a year-by-year basis. Although Ridker did not publish base year data, he did publish growth rates for the consumption of various minerals in the United States for 1971-85. These growth rates, along with values for 1971 consumption from table 4, were used to calculate "implied" values of consumption for 1980-83.

From the ratios presented in table 9 and figure 1, it is clear that quite a range exists for estimates of mineral consumption in 2000, at least for some minerals. Also, the ratios presented in table 12 and figure 2 show that the sum of the "implied" values of the forecasts or associated growth rates also followed the sum of the actual values of consumption for the period 1980-83 with varying degrees of accuracy, as one would expect given the range shown in table 9. In table 12 those ratios close to 1 indicate "implied" values quite close, in aggregate, to actual values over that period. As mentioned earlier, this kind of evaluation depends on the period of time chosen, and might show quite different results in a later time period.

Table 11.—Growth rates used to compute implied values of consumption for 1980-83

Commodity and area	Fischman[1] (4)	Leontief[2] (9)	Malenbaum[3] (11)	Ridker[4] (13)	BuMines[5] (14)
Aluminum:					
United States	4.0	4.0	4.3	4.83	4.4
World	5.3	ND	4.2	ND	5.4
Chromium:					
United States	ND	3.3	1.3	3.01	3.4
World	2.7	5.0	3.2	ND	3.3
Cobalt:					
United States	3.0	ND	3.2	3.41	2.9
World	2.3	ND	3.6	ND	3.0
Copper:					
United States	1.9	3.2	2.6	2.15	3.0
World	3.1	ND	2.9	ND	3.9
Manganese:					
United States	ND	2.4	3.4	2.37	1.4
World	2.6	5.3	3.2	ND	2.7
Nickel:					
United States	ND	3.1	2.2	3.17	4.0
World	ND	ND	3.1	ND	4.3
Tin:					
United States	ND	3.0	.9	2.16	.9
World	ND	4.2	2.1	ND	.9
Tungsten:					
United States	ND	3.6	2.1	3.90	4.6
World	ND	4.7	3.3	ND	3.5
Zinc:					
United States	.7	3.6	2.6	2.36	1.7
World	2.5	ND	3.3	ND	2.1

ND No data. [1] Computed; U.S. and world 1975-85. [2] Computed; U.S. 1972-2000; world 1970-90. [3] Published; U.S. and world 1975-85. [4] Published; U.S. 1975-85. [5] Published; U.S. and world 1978-2000.

Table 12.—1980-83 implied consumption divided by actual consumption
(Adjusted data base of each forecaster)

Commodity and area	Fischman (*4*)	Leontief (*9*)	Malenbaum (*11*)	Ridker (*13*)	BuMines (*14*)
Aluminum:					
United States	1.32	1.41	1.27	1.38	1.38
World	1.23	ND	1.04	ND	1.21
Chromium:					
United States	ND	1.75	1.29	1.27	1.52
World	1.09	1.22	.98	ND	1.18
Cobalt:					
United States	1.67	ND	1.60	1.37	1.55
World	1.53	ND	1.62	ND	1.46
Copper:					
United States	1.08	1.44	1.14	1.14	1.28
World	1.10	ND	1.03	ND	1.18
Manganese:					
United States	ND	2.01	1.97	1.76	1.69
World	1.29	1.71	1.33	ND	1.11
Nickel:					
United States	ND	1.58	1.39	1.38	1.51
World	ND	ND	1.09	ND	1.20
Tin:					
United States	ND	1.93	1.58	1.85	1.45
World	ND	1.63	1.21	ND	1.08
Tungsten:					
United States	ND	1.21	1.15	1.23	1.46
World	ND	ND	.98	ND	1.24
Zinc:					
U.S.	1.38	1.94	1.59	1.54	1.23
World	1.13	ND	1.15	ND	1.11

ND No data.

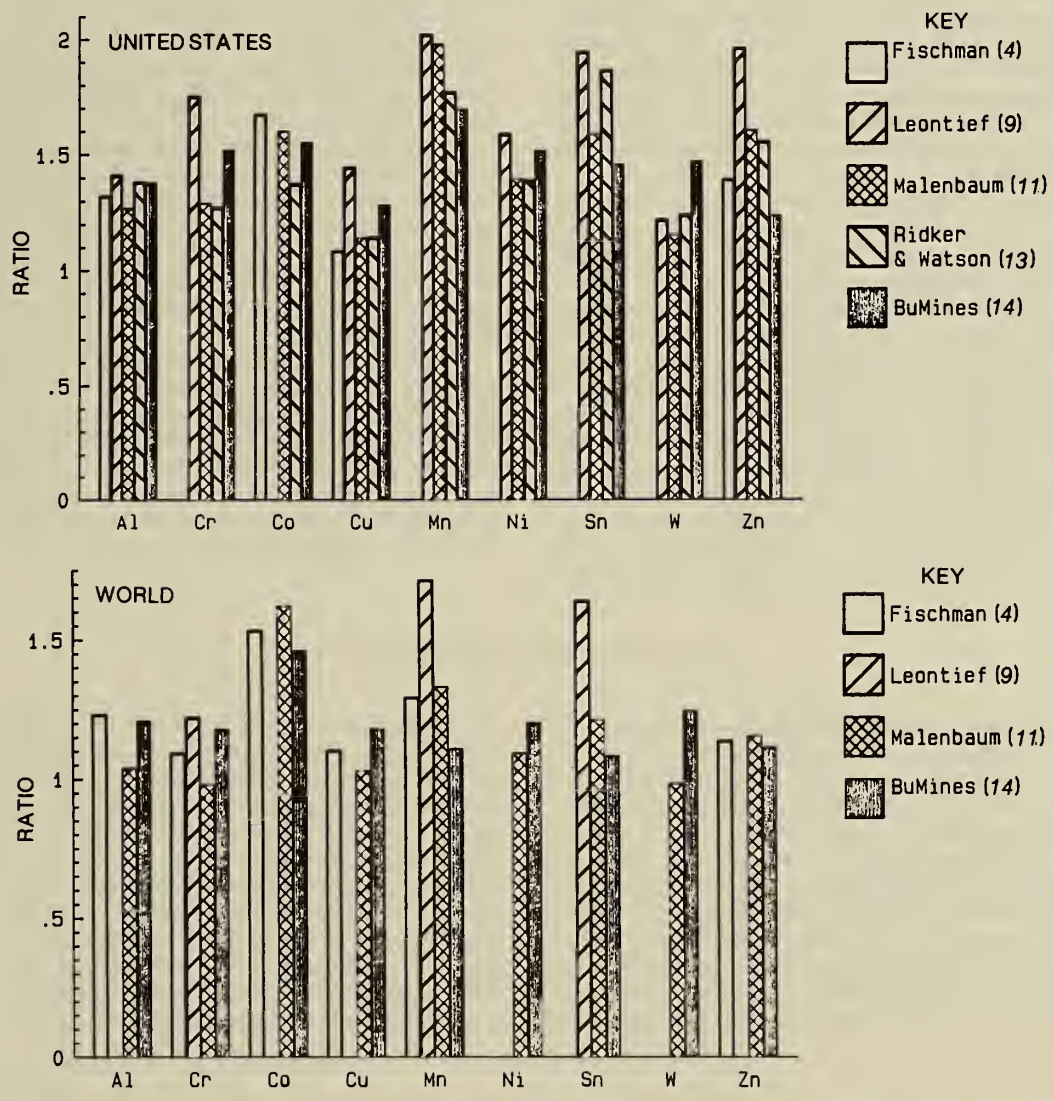

Figure 2.—Rebased 1980-83 implied consumption divided by 1980-83 actual consumption: United States and world.

GNP GROWTH ASSUMPTIONS

With the differences in forecasts clearly identified and measured, those interested in understanding the reasons for the differences can delve deeper into the various procedures and underlying assumptions. A description of the various methodologies used to generate the forecasts examined in the study is given in appendix A. These procedures are of varying degrees of complexity, with emphasis on different exogenous variables and relationships among variables. A thorough comparison of these procedures would involve assessing the assumptions behind each model, examining whether the procedures follow logically from the assumptions, determining if the outputs could be replicated, and assessing the costs and benefits of each model (*1*, p. 307). The costs include the initial cost of development, the cost of maintaining the model, and operating costs; benefits include the improvement in forecast accuracy, the level of confidence provided by the model, and the ability to assess alternative scenarios of the future. An extensive comparison of the procedures along these lines was beyond the scope of this study.

One assumption, however, the assumed rate of growth of gross national product (GNP) or gross domestic product (GDP), was compared because every forecast examined was based on some assumption about GNP or GDP growth. Also, most of the forecasting studies reviewed did make explicit their assumptions about growth in U.S. output, and some did so concerning growth in world output. Finally, the actual values of GNP and GDP growth in the period 1980-83 were readily available.

In the period 1980-83 economic growth in both the United States and the world was quite low. Real U.S. GNP grew at the rate of −0.3%, 2.5%, −2.1%, and 3.7% for 1980, 1981, 1982, and 1983, respectively (*5*, p. 205). World output grew at 2.0%, 1.6%, 0.6%, and 2.6% over the same years (*5*, p. 205). These rates, on average, were much lower than those assumed by the various forecasters, whose assumptions, of course, covered longer periods of time. (As the period 1980-83 seems to have been a cyclical low for business, in the longer run, their assumptions will probably turn out to be much more accurate.) Malenbaum (*11*, p. 38), for example, assumed a growth in U.S. GDP of 3.3% and world GDP of 3.5% over the period 1975-85. Fischman (*4*, p. 142) assumed a growth rate of U.S. GNP of 3.0% over the period 1980-85. Leontief (*9*, p. 33) assumed a 3.1% increase in U.S. GNP over the period 1972-2000. Ridker (*13*, p. 141) assumed a 2.9% increase in U.S. GNP over the period 1971-85 and over 3.5% rates of growth in the rest of the world. The Bureau of Mines[3] in its 1980 statistical estimates of U.S. consumption in 2000, assumed a 3.0% growth rate of U.S. GNP between 1978 and 2000. Overall the various forecasters made quite similar assumptions about GNP growth rates.

The methodology presented in the previous section resulted in ratios that when close to 1 indicate "implied" values quite close, in aggregate, to actual values over that period. Looking at table 12 in particular, what is striking is that almost all of the ratios are greater than 1. Thus most of the "implied" forecasts exceeded the actual value of consumption of these minerals during the period 1980-83.

Given the actual low values of GNP and GDP growth in the 1980-83 period, it is not too surprising that so many of the values in table 12 exceed 1. What may be surprising is that a number of projections resulted in ratios fairly close to 1, say within 10%, under the assumption of growth rates in economic output that were much higher than were actually experienced during this period. Since mineral consumption generally varies directly with economic output, one can readily hypothesize that if these forecasters had assumed lower values of economic growth rates, their forecasts of mineral consumption would have been lower, everything else remaining the same, and the implied consumption derived in the previous section would have been smaller. Again their estimates of GNP were for longer periods of time, and the 1980-83 period seems to have been a cyclical low for business. If lower growth rates had been used, however, ratios of the type found in table 12 might then have been far less than 1. In other words, the forecasters whose ratios were close to 1 in table 12 might have underestimated mineral consumption, if they had used in their procedures the growth rates that actually prevailed during the 1980-83 period!

Were these forecasters assuming more substitution for minerals, for instance, than actually took place? Or were they assuming more technological change, or more of a shift in the composition of GNP toward the service sector than actually occurred? What do these questions, and the possible answers, imply about projections currently being formulated? These and other questions arise from an analysis of this kind and illustrate its usefulness.

CONCLUDING STATEMENT

The comparison of mineral consumption forecasts from various sources involves numerous difficulties. The standardization procedure presented in this study provides a way, given adequate data, to overcome some of these difficulties. Standardized forecasts can be compared, in a precise fashion, to other standardized forecasts, and used for various purposes. For example, a set of standardized forecasts or standardized growth rates can be used to construct various scenarios of future events. Standardized forecasts can also be compared to available current data, using the growth rates associated with the forecasts to generate "implied" values for various years. The latter kind of comparison does not, however, provide a way of evaluating the underlying forecasting methodologies. In such an evaluation, assessments should be made of the procedures or models and of the predictions of the important causal variables within the models. In the case of mineral consumption forecasts, GNP predictions should be examined. The kind of examination of past forecasts for future time periods presented in this paper, along with a look at the underlying GNP predictions, was thought to be useful for decision makers and forecasters working with current data. Such an examination could help them adjust or confirm their own forecasts for future time periods.

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APPENDIX A.— REVIEW OF FORECASTING METHODOLOGIES

RESOURCE PROJECTIONS

Long-term projections of the U.S. demand for nonfuel minerals have been made for over 20 years. In the pioneer 1963 book *Resources in America's Future* (*7*), Landsberg projected for 1980 and 2000 both fuel and nonfuel minerals requirements, along with those for land, lumber, water, chemicals, and labor. The study compared the projected resource requirements with the 1960 U.S. resource base. These results were also presented in a condensed version of the original study entitled *Natural Resources for U.S. Growth* (*6*).

The starting point for these demand projections was a series of projections of population, labor force, and gross national product. Requirements for food, clothing, shelter, heat and power, transportation, durable goods, military equipment, outdoor recreation, etc. were then calculated. Next, these goods and services were translated into requirements for resource products such as agricultural raw materials, steel, lumber, and textile fibers. From these, in turn, the various demands on land, water, fuels, and other resources were estimated. Nearly all projections were made at three levels—low, medium, and high—with the middle levels considered most likely. (The low projections for 1980, in most cases, were closest to the actual 1980 levels of consumption.)

Long-term projections of resource needs on a global basis have been made for over 10 years. With the publication of *Limits to Growth* (*12*) in 1974, long-term global projections, already a subject of some debate, became controversial. In this book it was argued that the limits to growth on the planet would be reached sometime within the next century, if present trends continued. It was also argued that, given present resource consumption rates and the projected increase in these rates, most important nonrenewable resources would be extremely costly in the future (*12*, p. 66).

These conclusions were reached with the use of a simplistic world model that featured one general population, one geographic unit, one composite industrial output, one nonrenewable resource, and one class of pollutants. Within this highly aggregated model, the basic behavior mode of the world system was asserted to be exponential growth of population and capital, followed by collapse. Technological change had no impact on the essential problem, exponential growth in a finite and complex system (*12*, p. 145). Since the publication of *Limits to Growth*, arguments have been advanced both for and against the notion that man's progress would be limited in the future by resource scarcity.

STATISTICAL AND CONTINGENCY FORECASTING

In 1970 the Bureau of Mines began making mineral consumption projections for the United States and the rest of the world. These forecasts are presented in editions of *Mineral Facts and Problems*, which is published every 5 years. For the United States, two kinds of consumption forecasts are developed: statistical projections and contingency forecasts (*2*).

The statistical projections are calculated by the Division of Minerals Policy and Analysis, using linear regression analyses. Simple linear regression equations are used to approximate the end-use consumption of mineral commodities, where macroeconomic variables are selected as possible explanatory variables. For each end use of a particular mineral, a set of likely explanatory variables is chosen from among 75 possibilities (gross national product (GNP), gross private domestic investment (GPDI), U.S. population, new construction activity, and 71 different Federal Reserve Board industrial production indexes). Each variable within the chosen set is then used as the explanatory variable in a series of simple linear regressions over some historical period, usually starting in 1960, with the dependent variable being the end use of the material. From the equations so generated, the one with the highest R^2 (smallest sum of squared predicted errors) is chosen as the basis for deriving the statistical projection. The coefficients of this equation, plus a value of the explanatory variable projected to the year 2000 by a selected economic forecaster outside the Bureau, is then used to generate a projection for the end use.

The contingency forecasts are formulated by commodity specialists. These forecasts are judgmental and are based both on historical trends and on the specialists' knowledge of all developments, current and anticipated, that might have an impact on the future use of a commodity. In making these forecasts, the commodity specialists identify those problems or opportunities that might cause the consumption of a particular commodity to deviate from its historical trend. Using the statistical projections as a guide, the specialist arrives at estimates of low, high, and most probable consumption growth. Other specialists then critique these estimates, using, among other things, their knowledge of how the growth in consumption of the commodity in question might be affected by the growth of consumption of other commodities. All of the contingency forecasts utilize the statistical projections as their point of departure and assume the same economic conditions that underlie the statistical projections.

Individual commodity specialists also make the world consumption forecasts. For these forecasts, reliance is placed on trends in world economic growth, population growth, and the growth in consumption of selected minerals and materials. Also commodity specialists have access to forecasts made by knowledgeable consultants, mining companies, international commodity associations, and other economic groups.

INTENSITY OF USE

In a March 1973 study (*10*) for the U.S. Commission on Materials Policy, Professor Wilfred Malenbaum of the University of Pennsylvania's Wharton School of Finance and Commerce prepared projections of mineral demand by a methodology known as intensity of use. In this study, trends in overall economic growth, population growth, and growth in primary consumption of 11 minerals and materials were projected for the world, and for 10 world regions. The U.S. National Commission on Materials Policy was responsible for examining the feasibility of striking a balance between the national need to produce goods on the one hand and to protect the environment on the other. In October 1977 (*11*), following the publication of *Limits to Growth* and the oil price shocks brought on by the Organization of Petroleum Exporting Countries (OPEC), Malenbaum

updated his 1973 study at the request of the National Science Foundation. The 1977 report dropped some of his original commodities, added others, and revised downward the projections for consumption of aluminum, copper, iron, steel, and zinc.

Underlying the Malenbaum reports is the premise that long-term growth is not governed by supply limitations of any specific input materials. He argued that economic expansion is based on the human resources of the world's societies (*11*, p. 48), and that the aspirations and commitment to economic expansion on the part of public and private leaders mattered more than resource endowment and technology (*11*, p. 26). Thus, the direction of determination would run from gross domestic product (GDP) to material use. This assumption made it possible to project national and world economic growth in one part of the research effort without regard to the material needs appraised in the other part of the study.

Malenbaum thought that the record of growth in various parts of the world in the early 1970's lent support to the decisive role of quality inputs, both in rich lands where growth was impressive and in poor lands where the economic performance was more uncertain (*11*, p. 26). His appraisals of this situation, especially within the third world, led to his lower estimates of average GDP growth rates in the 1977 study than in the earlier study. In the 1977 study, he forecast the world in 2000 as having per capita GDP some 50% above 1971-75 levels in real terms, and as using two to three times the volume of raw materials in a year compared with average annual usage over 5 recent years. These results contrasted markedly with the conclusions of the 1973 study, where comparable ratios were reported between three and four. Thus, his expectation in 1977 was for a relative weakening of demand, and lower relative mineral prices. It was not a picture of a world confronted with limited resources (*11*, p. 122).

In brief, intensity of use (IOU) analysis is a procedure for translating GDP and population projections into mineral and material consumption projections, using tables that estimate the intensity with which minerals or materials will be consumed within a given country or region relative to per capita GDP levels. As used by Malenbaum, this analysis considers only primary use and disregards subsequent shipments of processed or manufactured minerals or materials to other regions. Hence, Japan, for example, is represented as having exceptionally high consumption levels, since Japanese exports are disregarded. Total world consumption of a given mineral or material is calculated as the sum of the consumption levels for the commodity projected for each region.

The following country groupings were used by Malenbaum:

1. Western Europe–Organization for Economic Cooperation and Development (OECD) countries in Europe.
2. Japan.
3. Other developed lands–Australia, Canada, Israel, New Zealand, Republic of South Africa.
4. U.S.S.R.
5. Eastern European Countries–Soviet bloc countries plus Albania and Yugoslavia.
6. Africa minus South Africa.
7. Asia minus Israel, Japan, China, Mongolia, North Korea and North Vietnam.
8. Latin America.
9. China plus Mongolia, North Korea and North Vietnam.
10. United States plus Puerto Rico and overseas islands.

Each of the 10 groups was considered to have a high enough degree of homogeneity to justify common assumptions with respect to changes in IOU of raw materials and in rates of total economic growth. Calculations regarding future mineral consumption levels are independent of similar calculations involving that region's consumption of other minerals and materials, and independent of any other region's consumption levels of any commodity. They are also independent of any explicit considerations regarding potential changes in supply levels, prices, or strategic or balance of payment positions.

Consumption of a given mineral or material within a given year is calculated on the basis of just three components: an exogenous projection of the level of overall economic activity (GDP) within a given region in a given year, an exogenous projection of the total population within the same region in the same year, and an "IOU table" showing the quantity of a given mineral or material per unit of that region's total GDP (a ratio known as the commodity's intensity of use) likely to be consumed within that region at various levels of regional per capita GDP. From the IOU table, the appropriate IOU value is obtained (expressed in terms of commodity units per unit of total GDP) for the regional per capita GDP level in question, interpolating or extrapolating as necessary. This IOU value is then multiplied by the exogenously estimated total regional GDP for that year.

On analysis of the historical record, Malenbaum found what seemed to be patterns strong enough to allow IOU projections. He thought that these patterns had a technological dimension, reflecting changes in use and efficiency of inputs to outputs, both taking account of changes in techniques (for input or output) and changes in market relationships associated with supply, demand, and public policy. Also he thought the analytic and descriptive literature on material use provided some guides for projecting the appropriate intensity levels. Primarily, however, it was the apparently systematic behavior of the measure that underlay his conviction of its usefulness in demand analysis for raw materials (*11*, p. 22).

The primary pattern found was formed by the IOU in a region and its per capita GDP. The IOU statistic increased as a function of increasing per capita GDP for less developed countries, and decreased for industrialized countries moving toward postindustrial service economies. Thus, mineral and metal consumption levels within a region whose economy is moving from industrialization to postindustrialization are projected using IOU statistics at various levels of per capita GDP that form an inverted U-shaped curve. For most of the materials Malenbaum considered, world intensity of use seemed to have already reached historical peak levels, mostly a decade or more back (*11*, p. 49). This conclusion supported his view that for the entire world, a large proportion of total world use will long continue to occur in the wealthier lands (*11*, p. 121).

The materials analyzed in the 1977 study were aluminum, chrome, cobalt, copper, iron ore, manganese, nickel, platinum, crude steel, tin, tungsten, and zinc. IOU data for these minerals were assembled for the same time intervals, 1951-75, with occasional data for 1934-38, on the same regional bases as were GDP and population. Most of the national product data and all of the population data were taken from United Nations sources. The output was converted to U.S. dollars in 1971 prices on the basis of exchange rate data. For the most part, the historical record was examined in the form of 5-year averages with recourse to individual years only to trace patterns of marked change within a

5-year period, a problem that arose especially for regions composed of countries not usually analyzed as a single unit (*11*, p. 25).

The material use data were from the Bureau of Mines, the United Kingdom's Summary of the Mineral Industry, the U.N. Department of Economic and Social Affairs, and occasional specialized private groups associated with producing and processing interests (e.g., the publishers of Germany's *Metal Statistics*).The consumption concept was "apparent consumption" or production minus exports plus imports plus changes in stocks (*11*, p. 29).

INTENSITY-OF-USE VARIATION

A variation on the IOU methodology was utilized in *World Minerals Trends and U.S. Supply Problems* (*4*) by Leonard L. Fischman of Resources For The Future. In this book the historical patterns of consumption for seven nonfuel minerals—aluminum, chromium, cobalt, copper, manganese, lead, and zinc—are examined. Projections of future patterns of consumption are offered, based for the most part on demographic and macroeconomic projections—that is, growth in GDP, or GDP per capita. The principal conclusion of his study was that the U.S. faces only one important type of mineral supply problem, based on its dependence on imports of certain minerals. The imports of a few of these minerals, chromium in particular, may be subject to disruptions that could cause a sharp upward movement of prices, with serious economic impacts (*4*, p. 3).

The general procedure for making the mineral commodity projections in this study was, first, to relate consumption of the refined metal to the appropriate macro indicator, usually GNP or GDP, and then to derive the ore or semirefined input into the refined metal; steel production was used as a macro indicator in several cases, yet it in turn was related to GNP or GDP (*4*, p. 144). Five-year moving averages of the ratio of consumption to GNP or GDP (averages of IOU ratios) were calculated for historical data periods of selected countries, in order to smooth out variations due to business cycles. Projections of the moving averages of these ratios were made, with the intention of achieving a similar smoothing pattern. The precise procedure used to make the projections was not specified, but it seems that the projections were judgmental. Elaborate statistical "filtering" methods were rejected as infeasible, and straight-line trends were rejected as inappropriate.

Fischman's world totals were based on the selected individual countries that account for the bulk of each commodity's utilization. By and large, these are the leading industrial countries for the refined metals, and a combination of industrial countries and other mineral-rich countries for the cruder forms of metals. It takes projections of the macroeconomies of only about a dozen countries, all told, according to Fischman, to provide the base for projecting the bulk of the consumption of all 18 commodity forms covered, plus crude steel. The aggregate consumption of the leading consumers of each form, though gradually declining in relation to world totals as new consumers enter the picture, may, it was hypothesized, be "blown up" fairly accurately to a world total for any given future year by extrapolating their declining share (*4*, p. 136).

Fischman argued that the difference between his macro assumptions and those of others should be taken as the expression of how he judged the future would unfold. He maintained that "whenever long-term commodity projections are based directly or indirectly on long-term projections of gross economic output, the commodity-projection accuracy tends to depend more upon the accuracy of the gross national or domestic product (GNP or GDP) projections than upon the parameters that join GNP/GDP to individual commodities" (*4*, p. 3). He concluded that "prior projections of world mineral consumption have been almost uniformly too high—principally because of overestimation of long-term growth rates in gross economic output of the principal consuming countries" (*4*, p. 137).

INPUT-OUTPUT

A quite different approach to the projecting of mineral requirements was used by Leontief in two studies. In *The Future of the World Economy* (*8*), published in 1977 with U.N. funding, a large and complex input-output model was constructed and used to, among other things, project the production and consumption of six nonfuel minerals. Overall, the model addressed the question of global resource requirements and the availability of food, mineral, and energy resources to meet these requirements to the year 2000. Macroeconomic variables, such as gross domestic product, consumption, investment, and the balance of payments, were projected for 15 regions into which the world's countries were aggregated. Also projected were a large number of sectoral outputs, including those of 30 manufacturing and service sectors, 4 agricultural sectors, 3 energy resource outputs, and 6 nonfuel mineral outputs: aluminum, copper, iron, lead, nickel, and zinc. In addition to output levels, the model tracked imports and exports in minerals, as well as all other traded goods. For nonrenewable fuel and nonfuel minerals, the model traced the cumulative resources produced in each region after each decade.

In a second book, *The Future of Nonfuel Minerals in the U.S. and World Economy* (*9*), the earlier study was updated and expanded, and the outlook for nonfuel minerals was stressed. Twenty-six nonfuel minerals were included in the second study: iron and ferrous metals (chromium, manganese, molybdenum, nickel, silicon, tungsten, vanadium), nonferrous metals (aluminum, copper, gold, lead, magnesium, mercury, platinum, silver, tin, titanium, and zinc), fertilizer-related minerals (phosphate rock, potash), and miscellaneous chemicals (boron, chlorine, fluorine, soda ash, and sulfur).

An input-output table shows the amounts of goods and services individual industries buy from and sell to each other in a particular year. Input coefficients are derived from such a table by dividing the column entries by the respective sectoral outputs. The coefficients show the amount of each input required to produce one dollar's worth of a sector's output. Each column describes the structure of a particular industry and, by giving a detailed, quantitative description of the inputs used by the industry, serves as an implicit representation of that industry's technology. Because each industry has its own column, the matrix is a structural description of the entire economy for a particular year. Similarly, a separate set of capital coefficients describes the stocks of buildings and equipment, as well as all kinds of working inventories, that each producing sector has to maintain to transform the proper combination of its inputs into its final output of goods and services (*9*, p. 20). The inputs of primary natural resources, such as agricultural land, water, and minerals, required by all producing sectors of the economy as well as households can also be depicted and

analyzed. Input-output tables are prepared by the Bureau of Economic Analysis (BEA) every 5 years (*9*, p. 23).

The world economy (in the U.N. World Input-Output Model) is subdivided into 15 regions that fall into 3 main groups: the developed regions, characterized by relatively high per capita income (North America, Europe, the Soviet Union, Oceania, South Africa, and Japan); the less-developed regions rich in natural resources (the Middle East, some of the South American countries, and some countries in tropical Africa); and the less-developed countries with few resources (*9*, p. 210). The model describes each region in terms of 45 sectors of economic activity, including various types of agriculture, mining, manufacturing, utilities, construction, services, transportation, communication, and pollution abatement. Though each region is initially treated separately, the model contains linkages that permit its users to trace the complex interconnections of trade, foreign investment, loans, interest payments, and foreign aid. The rates of regional or world economic growth, as determined by the regional rates of population growth, technological change, and savings, will to a great extent determine the global long-term requirements for nonfuel minerals.

Certain assumptions and projections underlie the Leontief projections. Assumptions about technological change and changes in recycling rates were both incorporated through changes in the mineral input coefficients. Changes in import requirements were handled in a similar fashion. Bureau of Mines projections of ratios of high and low levels of expected imports to primary demand were reconstituted into import coefficients, the ratio of imports to domestic output, so that they would be compatible with the structure of the model. By surveying special studies of future trends in material use, making extrapolations based on past trends, and then qualifying these crude estimates by discussions with experts on material use, the interindustry coefficients prepared for the World Model study were updated to reflect expected technological change. Labor and energy coefficients were similarly updated.

The final U.S. demand projections were based on projections made with the Bureau of Labor Statistics (BLS) macroeconomic model. The BLS model takes into consideration detailed projections of demographic trends and corresponding changes in the pattern of consumption, investment, exports, imports, and labor productivity. The size of the U.S. economy, measured by gross domestic product (GDP), was projected by the BLS to grow in real terms from 1972 to 2000 at an average annual rate of 3.1% (*9*, p. 23).

INPUT-OUTPUT AND INTENSITY OF USE COMBINED

A study published in 1980 used a combination of input-output and intensity of use methodologies in making projections. This study, *To Choose a Future* (*13*), by Ronald G. Ridker and William D. Watson, used a system of models, including a core input-output model, for its U.S. projections. Projections for the rest of the world were based on intensity-of-use calculations and projections of the growth of per capita income. The purpose of this study was to analyze the resource and environmental impacts on the United States of alternate rates of population and economic growth, with attention to international and technological developments and energy prices.

The system of models consisted of a number of special-purpose models linked to INFORUM, the University of Maryland's 185-sector, dynamic, macroeconomic-cum-input-output model of the U.S. economy, developed over a series of years by Clopper Almon and his students at the University of Maryland (*13*, p. 6). This system is known as SEAS/RFF (Strategic Environmental Assessment System/Resources For The Future). The SEAS/RFF system develops national U.S. economic forecasts through 2025 based on an exogenously specified set of demographic, macroeconomic, energy price, environmental policy, and resource policy assumptions. In turn, these forecasts form the basic economic inputs used by other models in the system to develop their more specialized forecasts. Forecasts are made at both national and regional levels. The model computes both dollar and physical estimates for all major fuels, some 20 nonfuel minerals, and 42 pollutants.

INFORUM is a dynamic forecasting model that joins aggregate GNP forecasts to the markets in which products are sold. The model determines industry outputs year by year based on forecasts for all product markets, for capacity, and for the availability of labor. Most of the final demand components are based on econometric equations derived from regressions performed by Clopper Almon and his associates (*13*, p. 418) on historical time series. Past levels of personal consumption expenditures were regressed against levels of disposable income, changes in disposable income, relative prices, time trends, and levels of consumption from previous years.

The six special-purpose models integrated with INFORUM into a common model were PRICE, which uses relative energy prices and price elasticities to alter energy demands, capital requirements, and GNP growth; TECHNOLOGY, which uses technological change assumptions to alter current and capital account flows; INSIDE, which provides greater detail on industrial output; ABATE, which calculates costs for abating pollution and sector purchases for abatement; ENSUPPLY, which uses assumptions about fuel availability and energy supply technology to determine energy supply and demand mixes; and MINERALS, which allows exogenous specification of stockpiles and import levels for selected minerals (*13*, p. 412). Together, these seven models form the national economic forecasting model (FORECAST) for the SEAS/RFF system. Linkage among all of the models allows population growth, energy price effects, technology change, abatement, energy supply constraints, and stockpiling and import constraints for minerals to be reflected in SEAS/RFF economic forecasts.

A number of assumptions and scenarios were used in the study. For instance, the study used the Census Bureau projection series D, E, and F for population projections. The E series, which was adopted as the baseline projection, assumes that the groups of women just entering the reproductive years will have a completed fertility rate of 2.1 births per woman. The D series assumes an average of 2.5 births per woman, reflecting a continuation of the trends of the last 50 years. Series F assumes 1.8 births per woman, reflecting a continuation of the trends of the last 5 years (*13*, p. 20). The study also assumed that the unemployment rate, which stood at 8.5% at the end of 1975, returned to between 4% and 4.5% by 1980 and remained within that range thereafter (*13*, p. 25). Two productivity assumptions were used: (1) worker-hour productivity returned by 1980 to the trend line of the 1948-68 period and (2) after 1968 the long-term growth rate in labor productivity shifted downward by 0.3% per year and only half of the shortfall from this new trend was made up by 1980 (*13*, p. 27).

Four different GNP projections were made for various world regions, using the following scenarios: high population and high economic growth, low population and high economic growth, low population and low economic growth, and two intermediate cases. These projections were based on a division of countries into four groups, each occupying a somewhat unique position in the world economy. The first group consists of the relatively developed, industrialized countries (OECD members, South Africa, Eastern Europe, and U.S.S.R.), where economic growth is largely a matter of maintaining growth in labor productivity and full employment of the labor force. Projections for countries other than the United States in this category begin by applying assumptions about growth rates in GNP per capita (an approximation for labor productivity) to the population projections (an approximation for the labor force). The projections are then modified to take into account the effects of higher petroleum and other import prices. Projections for the United States are derived from runs of the SEAS/RFF model. The second group of countries consists of OPEC members. The third group comprises countries whose growth rates are strongly dependent on foreign trade earnings in volatile international markets; for the most part, these countries are the principal nonfuel mineral exporters. The last group of countries consists of the resource-poor LDC's (*13*, pp. 42-44).

To solve the models, a trial value of disposable income was run through the system in order to determine personal consumption expenditures. Personal consumption expenditures were then used with estimates of public abatement expenditure, number of households, and interest rates to determine residential and public construction and other variables. This process continued until a GNP figure was obtained. The calculated GNP was then compared with a target GNP. If they differed, the level of disposable income was changed and the calculations began anew. Mineral demand projections for the United States were obtained by first estimating a value of gross domestic demand (*13*, p. 104)—that is, demand excluding exports that can be satisfied from primary production, secondary production, or imports. In those cases in which the SEAS/RFF model included a specific sector that could be associated with a specific mineral—aluminum, copper, iron, lead, or zinc—the demand projections were derived directly from the model. In all other cases, information from the Bureau of Mines (1975) on unit requirements (and changes in unit requirements over time) for each major mineral-using sector was combined with projections of the output of these sectors. With the exception of the fertilizer sector (a major user of phosphate rock, potash, and sulfur), for which projections were developed by other methods, sector projections were derived from the model. Secondary production, estimated by assuming that the percentage of demand satisfied by recycling remained the same as in the base period (roughly, the 1971-74 average), was then subtracted from these gross demand projections.

The mineral demand projections for the rest of the world were based on intensity-of-use relationships. It was assumed that mineral consumption per capita was a function of GNP per capita, and that this function changed over time as GNP per capita increased. The assumption was made that the relationship for other regions approaches that for the United States, though it never reaches it until the GNP per capita of the subject country catches up to that of the United States. The projections were made from four points in time, starting with historic data for 1971 for the region in question. A straight line was drawn from this first point through a point representing the projected relationship between consumption per capita and GNP per capita for the United States in 1985. The relationship for the region in 1985 was then found by locating its 1985 GNP per capita on that straight-line segment. The same procedure was repeated using the U.S. relationship in the year 2000 and then again in 2025. These estimates were then multiplied by population (*13*, p. 107).

APPENDIX B.—IMPLIED CONSUMPTION DIVIDED BY ACTUAL CONSUMPTION, 1980-83

Commodity and area	Implied/actual consumption, relative value				
	1980	1981	1982	1983	Average
ADJUSTED BUMINES DATA (*14*)					
Aluminum:					
United States	1.28	1.34	1.51	1.39	1.38
World	1.10	1.19	1.29	1.25	1.21
Chromium:					
United States	1.08	1.27	2.11	2.12	1.52
World	1.02	1.11	1.29	1.34	1.18
Cobalt:					
United States	1.25	1.68	2.04	1.45	1.55
World	1.21	1.52	1.79	1.44	1.46
Copper:					
United States	1.15	1.13	1.52	1.36	1.28
World	1.10	1.12	1.23	1.27	1.18
Manganese:					
United States	1.36	1.38	2.15	2.18	1.69
World	.95	1.12	1.13	1.27	1.11
Nickel:					
United States	1.38	1.43	1.71	1.56	1.51
World	1.06	1.20	1.27	1.27	1.20
Tin:					
United States	1.29	1.16	2.02	1.62	1.45
World	1.01	1.06	1.12	1.13	1.08
Tungsten:					
United States	1.12	1.13	2.01	1.97	1.46
World	1.06	1.15	1.40	1.42	1.24
Zinc:					
United States	1.25	1.06	1.42	1.25	1.23
World	1.05	1.11	1.14	1.12	1.11
ADJUSTED FISCHMAN DATA (*4*)					
Aluminum:					
United States	1.23	1.28	1.45	1.33	1.32
World	1.12	1.22	1.31	1.27	1.23
Chromium:					
United States	ND	ND	ND	ND	ND
World	.94	1.03	1.19	1.22	1.09
Cobalt:					
United States	1.34	1.80	2.19	1.56	1.67
World	1.28	1.59	1.86	1.50	1.53
Copper:					
United States	1.00	.97	1.28	1.13	1.08
World	1.04	1.06	1.15	1.18	1.10
Manganese:					
United States	ND	ND	ND	ND	ND
World	1.10	1.30	1.31	1.46	1.29
Nickel:					
United States	ND	ND	ND	ND	ND
World	ND	ND	ND	ND	ND
Tin:					
United States	ND	ND	ND	ND	ND
World	ND	ND	ND	ND	ND
Tungsten:					
United States	ND	ND	ND	ND	ND
World	ND	ND	ND	ND	ND
Zinc:					
United States	1.42	1.19	1.58	1.38	1.38
World	1.07	1.12	1.16	1.15	1.13

ND No data.

Commodity and area	Implied/actual consumption, relative value				
	1980	1981	1982	1983	Average
ADJUSTED LEONTIEF DATA (*9*)					
Aluminum:					
United States	1.31	1.37	1.55	1.42	1.41
World	ND	ND	ND	ND	ND
Chromium:					
United States	1.24	1.47	2.44	2.43	1.75
World	1.02	1.15	1.35	1.42	1.22
Cobalt:					
United States	ND	ND	ND	ND	ND
World	ND	ND	ND	ND	ND
Copper:					
United States	1.30	1.28	1.70	1.54	1.44
World	ND	ND	ND	ND	ND
Manganese:					
United States	1.61	1.64	2.56	2.64	2.01
World	1.41	1.71	1.75	2.01	1.71
Nickel:					
United States	1.46	1.51	1.77	1.61	1.58
World	ND	ND	ND	ND	ND
Tin:					
United States	1.66	1.52	2.71	2.22	1.93
World	1.46	1.58	1.72	1.79	1.63
Tungsten:					
United States	.95	.94	1.67	1.61	1.21
World	ND	ND	ND	ND	ND
Zinc:					
United States	1.93	1.65	2.25	2.01	1.94
World	ND	ND	ND	ND	ND
ADJUSTED MALENBAUM DATA (*11*)					
Aluminum:					
United States	1.18	1.24	1.39	1.29	1.27
World	.97	1.04	1.11	1.06	1.04
Chromium:					
United States	.94	1.10	1.78	1.75	1.29
World	.84	.93	1.08	1.11	.98
Cobalt:					
United States	1.27	1.72	2.10	1.49	1.60
World	1.32	1.67	1.98	1.61	1.62
Copper:					
United States	1.03	1.01	1.36	1.21	1.14
World	.97	.99	1.07	1.10	1.03
Manganese:					
United States	1.54	1.60	2.52	2.63	1.97
World	1.13	1.35	1.35	1.52	1.33
Nickel:					
United States	1.29	1.33	1.54	1.40	1.39
World	.98	1.09	1.15	1.13	1.09
Tin:					
United States	1.40	1.26	2.20	1.77	1.58
World	1.12	1.18	1.27	1.29	1.21
Tungsten:					
United States	.92	.90	1.57	1.49	1.15
World	.84	.91	1.10	1.12	.98
Zinc:					
United States	1.59	1.35	1.85	1.64	1.59
World	1.08	1.14	1.19	1.20	1.15

ADJUSTED RIDKER DATA (*13*)

Commodity (United States data only)	Implied/actual consumption, relative value				
	1980	1981	1982	1983	Average
Aluminum	1.27	1.34	1.52	1.41	1.38
Chromium	.90	1.07	1.76	1.76	1.27
Cobalt	1.09	1.47	1.80	1.28	1.37
Copper	1.05	1.02	1.35	1.20	1.14
Manganese	1.40	1.44	2.25	2.31	1.76
Nickel	1.27	1.31	1.55	1.41	1.38
Tin	1.61	1.47	2.58	2.10	1.85
Tungsten	.95	.95	1.69	1.64	1.23
Zinc	1.55	1.32	1.78	1.57	1.54

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